Small Grains

Economic and Biological Benefits of Intercropping Berseem Clover with Oat in Corn-Soybean-Oat Rotations

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Sustainability of Iowa agriculture may require change from predominantly a corn (*Zea mays* L.)-soybean [*Glycine max* (L.) Merr.] rotation to more diverse cropping systems. Alternative crops are vital for providing temporal diversity. Reincorporating small grains into a three-crop rotation with corn and soybean can provide greater temporal diversity, especially if a forage legume is included as a companion crop. A field study was established in 1991 on a Kenyon (fine-loamy, mixed, mesic Typic Hapludoll) soil to evaluate the economic and biological benefits of an oat (*Avena sativa* L.) crop underseeded with berseem clover (*Trifolium alexandrinum* L.) in a three crop- rotation. Two rotation treatments were compared: (i) corn-soybean-oat and (ii) corn-soybean-oat intercropped with berseem clover. In 1992, 1993, 1994, and 1995, oat grain yield was not significantly changed when berseem clover was underseeded with the oat crop. However, in 5 yr, oat underseeded with berseem clover produced up to 70% more biomass (harvested material without the grain) than sole-crop oat straw. The biomass (40% oat straw and 60% berseem clover forage) also had adequate digestible material (51%) to be considered as low quality forage. Berseem clover regrowth after oat grain harvest produced an average 1.2 tons/acre of forage, which could have been harvested for hay or left in the field as green manure. During this trial, berseem clover regrowth was left as groundcover and green manure, which contributed an average of 39 lb N/acre to the succeeding corn crop. Corn grain yields following berseem clover were 10% higher over the trial period. Soybean grain yields were the same for both treatments. Intercropping berseem clover with oat returned an average of $39/acre more than sole-crop oat. This study demonstrated both economic and biological advantages for more diverse cropping practices.

INCREASED CORN AND SOYBEAN production throughout the Midwest has decreased crop diversity, contributed to significant environmental problems, and limited opportunities to integrate livestock into the cropping system. In Iowa, approximately 78% (12 million acres of corn and 9 million acres of soybean) of 27 million harvested acres are under corn and soybean production (Iowa Agricultural Statistics, 1992–1996). Approximately, 65% of corn acres are managed with a corn-soybean crop sequence, 30% with continuous corn, and the rest with other rotations. Research in Minnesota (Crookston et al., 1991) suggests that adding a third crop, and possibly more, between the corn-soybean sequence will create a superior cropping system, particularly from the corn and soybean yield standpoint. However, finding a grain crop that compares economically with corn and soybean is difficult. Small grains are a favorable candidate for a three-crop rotation. The inclusion of small grains in crop rotations in Iowa, however, has been unpopular, largely because of low grain market value and high variability in grain yield. Oat accounts for approximately 89% of all small grains grown in Iowa. More than 750 000 acres of oat are planted each year, but only 225 000 acres are harvested for grain (Iowa Agricultural Statistics, 1992–1996). The remaining acres are harvested as hay or silage, or to satisfy government program requirements.

The use of cover crops is increasing for several reasons. They reduce soil erosion (Ebelhar et al., 1984; Scott et al., 1987), increase water infiltration (McVay et al., 1989; Wilson et al., 1982), and improve soil productivity (Hargrove and Frye, 1987). The low percentage of groundcover with annual grain crops, particularly from soybean, results in soil exposure to water and wind erosion, increases potential for leaching of soil nitrate N, and reduces N availability for the subsequent crop. Small grains permit the inclusion of forage legumes as a cover crop in the crop rotation. In a no-till system, legume winter cover crops provided biologically fixed N equivalent to 58 to 120 lb/acre of fertilizer N to grain sorghum [*Sorghum bicolor* (L.) Moench] and other succeeding summer crops (Blevins et al., 1990). In the midwestern USA, oat easily accommodates inclusion of a forage legume as a companion crop or cover crop after grain harvest. Legume cover crops may contribute N to the subsequent crop (corn or grain sorghum) and reduce the fertilizer requirement by 65 lb N/acre or more (Hargrove, 1986; McVay et al., 1989; Holderbaum et al., 1990). In northern climates, approximately 90 lb N/acre can be contributed to the succeeding corn crop by underseeded or interseeded legumes (Bruulsema and Christie, 1987).

Conventional small grain-legume combinations in Iowa consist of oat underseeded with alfalfa (*Medicago sativa* L.) or mammoth red clover (*Trifolium pratense* L.). Rye (*Secale cereale* L.) or oat mixtures with hairy vetch (*Vicia villosa* Roth subsp. *villosa*) seeded after small-grain harvest is also a common practice. However, chemical or mechanical elimination of these cover crops in the fall or early in the spring before planting or germination of the succeeding crop is a major management consideration. Spring regrowth of bien-

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Abbreviation: NFRV, N fertilizer replacement value.

nial cover crops may deplete soil moisture to the extent that subsequent crop grain production is decreased (Ebelhar et al., 1984; Frye et al., 1988; Badaruddin and Meyer, 1989; Hesterman et al., 1992).

Selecting an appropriate legume cover crop requires consideration of the legume characteristics, its associations with the primary crop, management practices, and environmental factors. Berseem clover, commonly known as Egyptian clover, grows rapidly after seeding and, in contrast to traditional legumes, is a true annual that winter-kills in Iowa. Berseem clover also responds very well to multiple cutting schedules (Baldridge et al., 1992), has high forage quality, and has abundant biomass production (Brink and Fairbrother, 1992; Singh et al., 1989). Singh et al. (1989) found that the oat-berseem clover combination may produce 4.5 tons/acre of high quality biomass. Oat underseeded with berseem clover offers alternative harvesting options during the growing season. For example, in an anticipation of poor oat grain yield or quality, the producer may harvest the small grain-berseem combination as hay or silage. Grazing has also been investigated, and there have been no reported cases of bloat for ruminant animals (Baldridge et al., 1992; Sims et al., 1991).

The amount of legume N contributed under different environmental, cropping, and soil conditions is unclear. Most evaluations of legume N contributions have been conducted specifically with the legume as a green manure or within a rotation following the complete life cycle of the legume species. Companion legume crops are not often grown to maturity and are subject to competition from primary crops. In particular, the N_2 fixation of a companion legume crop may be very susceptible to shading within the intercropping conditions (Nambiar et al., 1983). Thus, N contributions by a companion legume-cover crop on an annual basis remains unknown.

Tillage practices also influence availability of the legume-contributed N to the succeeding crop (Heichel, 1987), especially since plowdown or incorporation of biomass does not occur in no-till and ridge-tillage systems. Studies in Nebraska showed that, in a no-till system, a hairy vetch cover crop increased soil nitrate, but not until 50 to 78 d after the succeeding corn crop was planted (Brown et al., 1993). This increase in soil nitrate occurred after corn silking, at which time more than 70% of the plant N need had already been met and additional mineralized N has little effect on yield (Hanway, 1963).

The benefits of legume cover crops grown in rotation have been widely demonstrated. Major limitations in determining the environmental importance and economics of intercropped legume cover crops remains because little reliable data exist for specific environments and crop rotation sequences. The objectives of this study were to evaluate the economic and biological benefits of an oat crop underseeded with berseem clover in a three-crop rotation.

MATERIALS AND METHODS

A field experiment was conducted for 5 yr (1991–1995) on Kenyon soil with a maximum 5% slope at the Northeast Iowa Research Farm near Nashua. The experimental design was a split-plot with two whole plots (three-crop rotation) randomized within four blocks. Whole plots (Treatments I and II) included corn-soybean-oat (Fig. 1). Each crop within Treatments I and II was grown in a 15 by 200 ft plot and rotated annually. The corn plot was then split into four 50-ft subplots to evaluate N fertilizer rates. Corn (24 000 seed/acre) and soybean (160 000 seed/acre) were planted in six 30-in. rows. Oat was sown at a rate of 120 lb/acre in 20 rows with 7.5-in. spacing using a no-till drill.

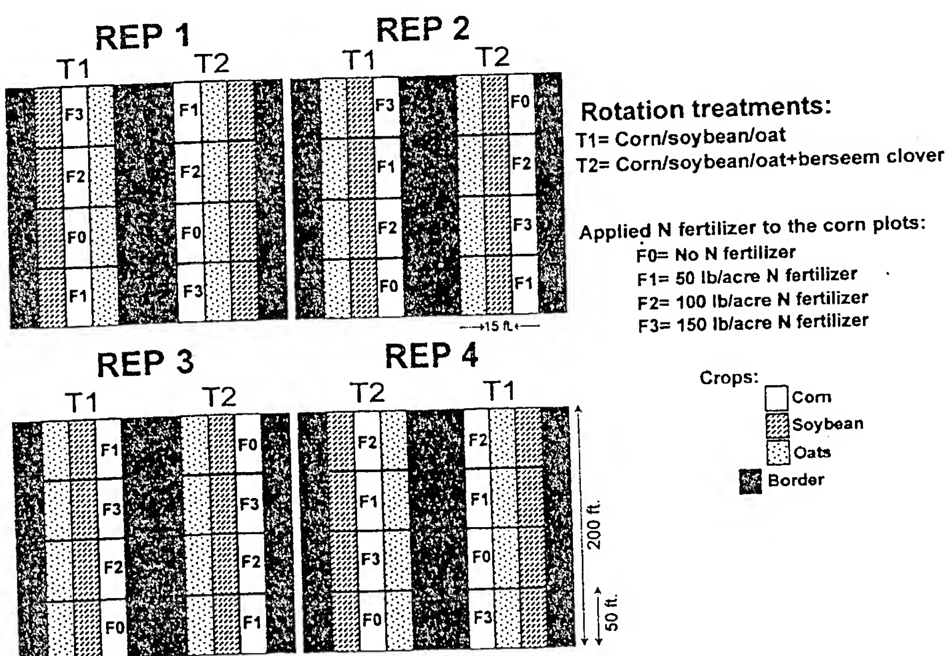


Fig. 1. Plot plan, rotation treatments, applied N fertilizer to the corn plots, plot and subplot sizes, and randomization of treatments within each replication.

Table 1. Monthly rainfall during growing seasons and accumulative rainfall during oat production (1991–1995).

Month	Rainfall by year					Departure from normal by year				
	1991†	1992‡	1993§	1994¶	1995#	1991	1992	1993	1994	1995
	in.									
April	6.86	3.60	3.45	2.29	3.99	+3.58	+0.32	+0.17	−0.99	+0.71
May	7.00	2.10	3.81	2.76	2.42	+2.83	−2.07	−0.36	−1.41	−1.75
June	6.14	2.12	6.95	6.57	6.74	+1.60	−2.42	+2.41	+2.03	+2.20
July	2.33	7.19	9.12	6.89	5.51	−2.01	+2.85	+4.78	+2.55	+1.17
August	4.93	2.65	8.70	2.17	5.74	+0.92	−1.36	+4.69	−1.84	+1.73
September	2.10	4.21	2.97	2.30	2.29	−1.90	+0.21	−1.03	−1.70	−1.71
October	4.11	0.88	1.41	3.39	2.30	+1.47	−1.76	−1.23	+0.75	−0.34
November	3.26	5.50	1.34	2.39	0.72	+1.60	+3.84	−0.32	+0.73	−0.94
Total	36.73	28.25	37.75	28.76	29.71	+8.09	−0.39	+9.11	+0.12	+1.07
During oat production	22.33	12.21	16.41	16.90	13.14					

† 1991—The wettest April in more than 40 yr.
‡ 1992—November received 3.8 in. more rain than normal, wettest in more than 40 yr.
§ 1993—Fourth wettest growing season in over 40 yr.
¶ 1994—Dry April and May, and above-normal rainfall in June and July provided excellent growing conditions.
# 1995—Hail on 22 July severely damaged corn and oat crops with minor damage to soybean crop.

For Treatment I, a mixture of oat (90 lb/ acre) and hairy vetch (27 lb/acre) was seeded as a true cover crop approximately 1 mo after oat harvest. The goals were to obtain soil cover and fixed N during the fall and spring and to kill the hairy vetch with 2,4-D after planting but prior to emergence of the subsequent corn crop in the spring. This failed miserably during spring of 1992 and the hairy vetch regrowth was killed with glyphosate before any substantial growth or apparent N_2 fixation occurred. Therefore, in Treatment I, seeding a cover crop was discontinued. The oat phase of this rotation is therefore referred to as sole-crop oat for the remainder of this discussion. No herbicide or fertilizer were applied to the oat crops.

For Treatment II, berseem clover was seeded at 15 lb/acre with 120 lb/acre of oats in spring. The oat cultivar for 1992 through 1995 was changed from a mid-season to short-season tall variety after extensive berseem clover growth interfered with oat grain harvest in 1991.

For both Treatments I and II, four N rates (0, 50, 100, and 150 lb N/acre) as ammonium nitrate (except in 1995, urea was used) were applied by hand to the corn subplots prior to first cultivation. Corn and soybean were both cultivated two or three times. In late August 1993, oat plots in Treatment I were tilled with a cultivator to control excessive weed growth after grain harvest. Pre-emergence weed control was accomplished by banding granular alachlor at planting. Phosphorus and K were not applied to any of the crops because the soil tested high for both nutrients.

Corn and soybean grain yields were determined by harvesting 40 ft of the two center rows of subplots using a small-plot combine. Grain yields were adjusted to the basis of 15.5 and 13% grain moisture for corn and soybean, respectively. Oat grain, straw, and biomass (minus grain) yields were determined by hand-harvesting 3 by 3 ft sections from the center of each subplot.

In Treatment II, at the time of oat grain harvest, berseem clover forage was separated from oat straw to determine straw-hay mixture ratio. Subsamples of oat straw and straw-hay were taken to the Iowa State University animal nutrient lab for in vitro evaluation of dry matter feed value using the direct acidification method (Marten and Barnes, 1980). Dry matter production from berseem clover regrowth was measured before the killing frost occurred each year. Plant material was dried and ground to pass a 0.04-in. screen with a Cyclone mill. Nitrogen concentration was determined by micro-Kjeldahl digestion (Bremner, 1965).

In many studies (Hargrove, 1986; Bruulsema and Christie, 1987; McVay et al., 1989) an indirect measurement of the legume cover crop's N contribution is determined by comparing yield response of the succeeding crop to N fertilizer with and without a cover crop. However, climatic conditions, nutrient uptake efficiency of the crop, N fertilizer type, and timing of application will affect the crop response to N fertilizer. To determine N fertilizer replacement values (NFRV) for the berseem clover cover crop, corn grain yield response to N fertilizer rates was used. Quadratic regression equations were obtained using corn grain yields following sole-crop oat (Treatment I) and oat intercropped with berseem clover (Treatment II). The NFRV was estimated by substituting 0 N rate grain yield for corn following oat underseeded with berseem clover into the quadratic equation of corn grain yield following sole-crop oats.

Statistical analyses were conducted using SAS (SAS Institute, 1985) analysis of variance procedures. A comparison of means was performed by using Fisher's LSD (the least significant difference at the 5% probability level) where significant treatment mean squares were found.

For economic evaluation, costs of oat production were estimated, using Cost of Crop Production in Iowa (Duffy and Judd, 1990–1995). Market-year average price (Iowa Agricultural Statistics, 1992–1996) and land value for Floyd County was used. For both treatments, production cost included: machinery, inputs, land value, and labor cost for oat grain and straw or hay (oat straw and berseem clover forage) harvest.

RESULTS AND DISCUSSION

Oat yields (1992–1995) were not affected by N fertilizer applied to corn plots in both rotations. Therefore, average yields of subplots for oat are presented. Total rainfall during oat production every year except in 1992 was above normal (Table 1).

Oat Grain and Biomass Yields

Oat grain yields in 1992, 1993, 1994, and 1995 were not significantly different for sole-crop plots and those interseeded with berseem clover (Fig. 2). In contrast, biomass (minus grain) production was 67, 150, 68, and 19% greater with berseem clover than without it from 1992 to 1995, respectively (Fig.2). High year-to-year variability of grain yield is a major reason why Iowa farmers grow very little oat. This variability was also evident in our field study. On the other hand, straw, and especially biomass (minus grain), production in the 5 yr was much less variable.

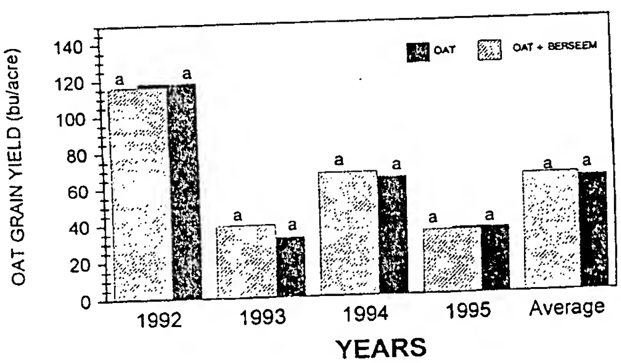
In 1992, the apparent soil productivity (2 yr of soybean 1990 and 1991) combined with excellent climatic condition resulted in record high oat grain production in Iowa. Oat grain production suffered in 1993 because of excessive rainfall. However, berseem clover biomass (minus grain) pro-

duction was 2.5 tons/acre at oat grain harvest (Fig. 2) and 1.4 tons/acre regrowth at the end of the growing season (Table 2). In 1995, hail damage in July caused severe oat grain loss and also moderately reduced berseem clover regrowth.

Most winter legume cover crops used in Iowa either delay planting or compete with the succeeding crop. Berseem clover, however, was winter-killed and presented no management obstacle for corn during next spring. In the 5 yr of this study, berseem clover has shown favorable intercropping characteristics with oat and seems adapted to the climatic conditions in Iowa. Feed quality of berseem clover forage and straw mix (oat straw 40% and berseem clover hay 60%) were high compared with straw with in vitro dry matter disappearance rates of 51 and 36%, respectively.

Oat Treatments Economics

Intercropping resulted in greater profits than sole-crop oat each year, primarily due to larger biomass (minus grain) production. In Treatment II, intercropping berseem clover with oat had better economic return than sole-cropped oat (Table 3). Additional costs of intercropping berseem clover included seed, extra baling, and labor costs. Production costs were not separated between oat grain and straw or hay production and only calculated as costs for a grain portion. Regrowth of berseem was left as a cover crop (green manure) to protect the soil and contribute N to the succeeding corn. The direct value of berseem clover regrowth or indirect value of contributed N to the following corn crops was not considered as profit.



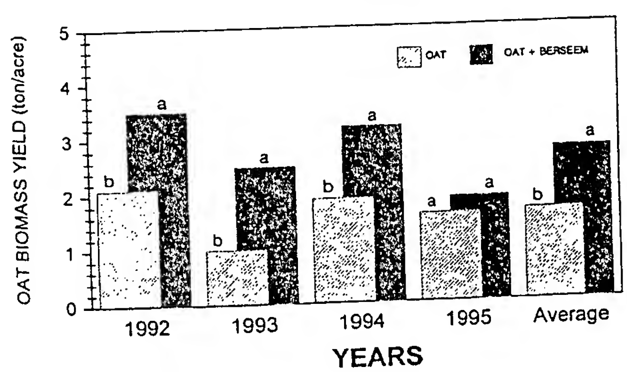


Fig. 2. Oat grain yield and biomass (minus grain) production at grain harvest time in both treatments. Yields with the same letter for a given year not different ($P > 0.05$).

Table 2. Primary oat crop planting, harvesting, and first killing frost occurrence, and potential N contribution of berseem clover from aboveground cover biomass.

Year	Date			Berseem clover regrowth		
	Oat		Killing frost			
	Planting	Harvesting		DM†	N	N yield
				ton/acre	%	lb/acre
1991	7 Apr.	29 July	20 Sept.	1.3	2.49	65.0
1992	15 Apr.	19 July	5 Nov.	1.1	2.32	51.0
1993	10 May	30 July	29 Sept.	1.4	2.35	65.8
1994	11 Apr.	19 July	1 Nov.	1.2	2.41	57.8
1995	25 Apr.	20 July	22 Oct.	1.2	2.44	58.2
Means				1.2	2.40	59.6

† Dry matter was measured from aboveground biomass at the end of the cropping season.

Corn Yield

Corn responded similarly to applied N fertilizer in both rotation treatments. When N was not the limiting factor (150 lb N/acre subplots), corn grain yield (averaged for the 5 yr) was significantly higher for Treatment II than for Treatment I (Fig. 3). Above-normal rainfall, low air temperature, and below normal days of sunshine created poor growing conditions in 1993. Weed control problems (predominantly common dandelion [*Taraxacum officinal* W.]) in the 1994 corn plots after berseem clover resulted in relatively lower yield than in previous years. Hail in 1995 resulted in severe damage to corn leaves, which consequentially reduced grain yield by 35 to 40 %.

Soybean Yield

Adding berseem clover with oats had no effect on soybean yield (Fig. 2). Soybean yields also were not affected by N fertilizer applied to corn plots in both rotations. In 1995, soybean suffered 5 to 10 % hail damage.

Berseem Clover Nitrogen Content

Higher corn yields following oat plus berseem clover may be due to the N contribution of the legume cover. At the end of the growing season in 1991, 1992, 1993, and 1994, the amounts of berseem clover biomass that remained on the soil surface were 1.3, 1.4, 1.2, and 1.2 tons/acre, respectively. The N concentration of the dry matter was approximately 2.4% (Table 2). The potential N contribution of berseem clover from aboveground biomass was therefore consistent at approximately 60 lb N/acre per year. Determining N contribution to succeeding crops by calculating shoot biomass N content can be unclear (Heichel, 1987) because of potential N losses, tillage effects, and uncertain mineralization rates.

Estimations of NFRV for 1992, 1993, and 1994 by using corn response curves were 63, 165, and 0 lb N/acre, respectively. In 1995, corn plants were severely damaged by hail. This resulted in confounded grain response curves and estimates of NFRV were inconclusive. The N fertilizer rates were not sufficient to optimize corn grain yield in 1993 because above-normal precipitation and flooding resulted in a linear corn grain yield response to applied N. In 1994,

Table 3. Economic comparison of the oat production (at oat grain harvest) in both treatments at the Northeast Iowa Research Center (1991–1995).

Crops	Corn-Soybean-Oat 1991	1992	1993	1994	1995	Corn-Soybean-Oat + Berseem 1991	1992	1993	1994	1995
Oat-Grain										
Yield bu/acre	60	118	32	64	35	47	116	39	67	34
Net $/acre	–$69	$15	–$98	–$56	–$88	–$129	–$33	–$128	–$90	–$124
Straw										
Yield ton/acre	1.1	2.1	1.0	1.9	1.6	--	--	--	--	--
Net $/acre	$50	$95	$50	$104	$99	--	--	--	--	--
Biomass (minus grain)										
Yield ton/acre	--	--	--	--	--	2.7	3.5	2.5	3.2	1.9
Net $/acre	--	--	--	--	--	$135	$175	$137	$208	$142
Total net profit/acre	–$19	$110	–$48	$48	$11	$6	$142	$9	$118	$18
Total net profit/acre 5 yr			**$20**					$59		

Years	1991	1992	1993	1994	1995
Price $/bu or ton†					
Grain	$ 1.19	$1.34	$1.39	$1.41	$1.65
Straw	$45.00	$45.00	$50.00	$55.00	$62.00
Biomass (minus grain)	$50.00	$50.00	$55.00	$65.00	$75.00
Cost $/acre‡					
Oat + straw	$140§	$143	$143	$146	$146
Oat+biomass(minus grain)	$185¶	$188	$182	$185	$180

† Market-year average price in Floyd County (Iowa Agricultural Statistics, 1992–1996)
‡ Total production cost (Duffy and Judd, 1990–1995).
§ Production cost included oat grain and straw harvest (but only calculated as cost for grain oat production).
¶ Production cost included oat grain, hay harvest, and extra cost associated with underseeded berseem clover (but only calculated as cost for grain oat production).

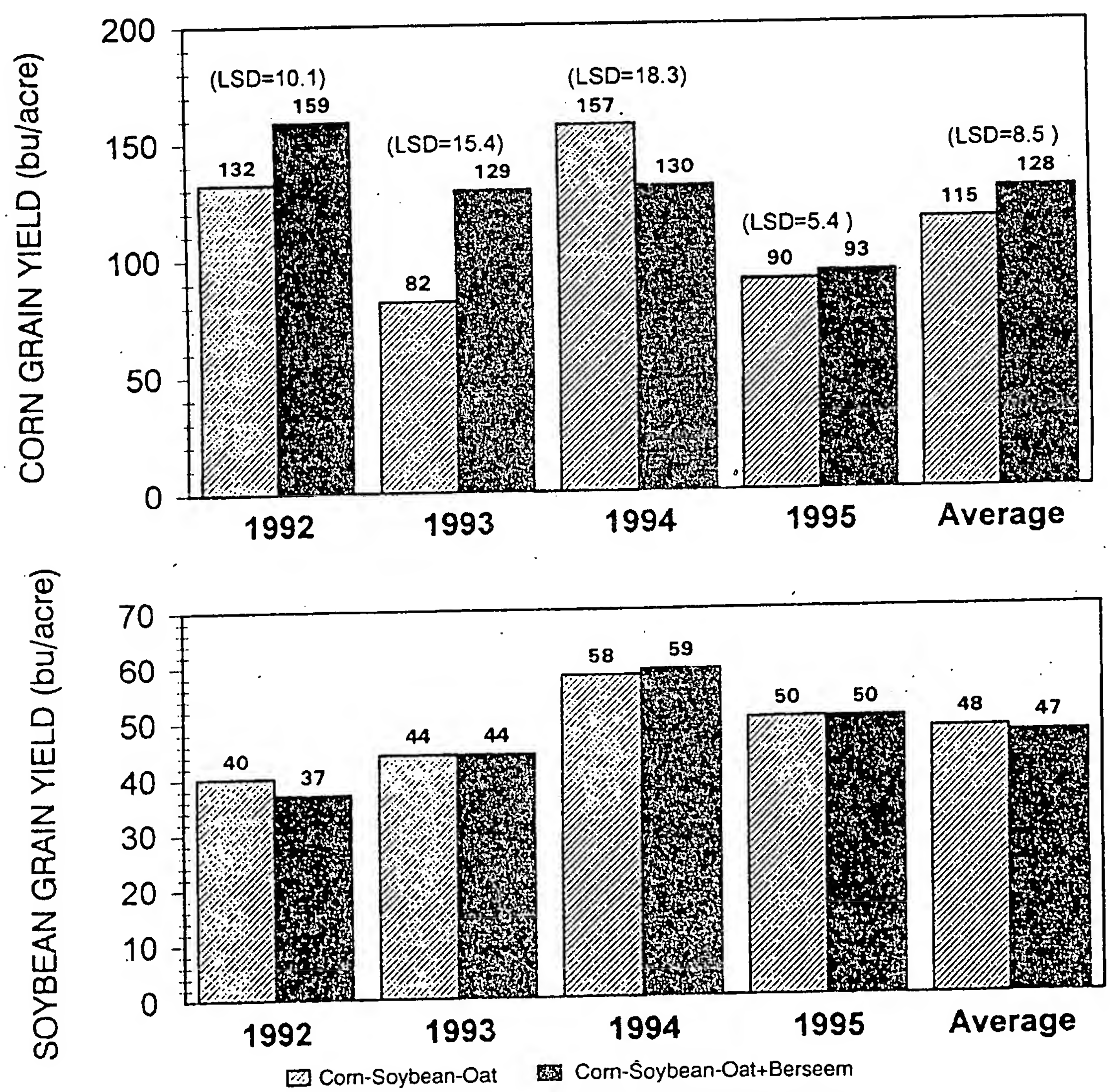


Fig 3. Corn and soybean yields for two rotation treatments in 1992, 1993, 1994, and 1995. LSD = least significant differences between treatments for each crop within a year.

response curves were similar in both treatments. Additionally, Treatment II had high weed pressure, which affected the corn grain yield. In 1992, a normal year, potential N contributed by the cover crop (aboveground portion) in fall and estimated NFRV from the succeeding corn crop were similar. Estimated NFRV using average corn grain (1992, 1993, and 1994) response curve to N fertilizer indicated that approximately 39 lb N/acre was contributed by berseem clover (Fig. 4).

The effect of a berseem cover crop on soil productivity and soil physical properties were not part of the research objectives; however, an adjunct study (Sawchik, 1994) indicated that berseem clover provided 79% groundcover until corn planting.

CONCLUSIONS

Intercropping berseem clover with oat increased total biomass production without reducing oat grain yield. Regrowth of berseem clover following oat harvest can be harvested for hay, fed as fresh green-chop, ensiled, grazed, or left as green manure. Using berseem as green manure to the cropping system provided the equivalent of 39 lb N/acre to a subsequent corn crop. Interseeding oat with berseem clover increased profit from the oat portion of a 3-yr corn-soybean-oat rotation by increasing biomass quality and quantity. Additionally, berseem clover provides a high-density cover crop, and improves soil productivity. The use of berseem clover as a cover crop could make growing oat more profitable and, with decreasing government payments, it may become a major viable alternative crop for farmers in the Midwest.

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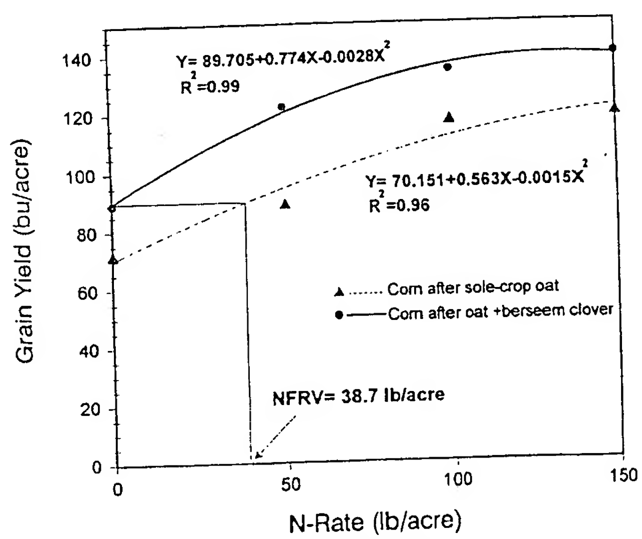

Fig. 4. Corn grain response to N fertilizer (1992, 1993, and 1994 average) and evaluation of N fertilizer replacement value (NFRV).